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Texturing of skin-pass rolls by pulsed laser dispersing

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ABSTRACT

Skin-pass rolling is a substantial process step in the production line of sheet material for automotive applications. Textured rolls are used to emboss an immaterial surface structure on sheets for improving their formability in subsequent deep drawing operations. In this paper, state of the art techniques for texturing skin-pass rolls are discussed in order to assess their ability to meet optimal tribological parameters. Two main problems are identified: firstly, structured rolls are affected by ongoing wear limiting the operating time and necessitates perpetual maintenance. Secondly, state of the art techniques are not able to exploit the theoretically known potential of immaterial surface structures for enabling micro-lubrication mechanisms due to geometrical inadequacies.

Based on these findings, a new approach for texturing of skin-pass rolls is introduced. The technique uses a localised dispersing of hard ceramic particles by use of pulsed laser radiation. It is shown in this paper that this technique allows the creation of elevated structures with high hardness on the surface of 1.2379 cold-working steel. The wear behaviour of such textured rolls was investigated in a lubricated twin-disc-test. The experiments show that no significant wear of the laser produced structures occur during the test duration. The observed results lead to the assumption that the proposed technique allows the creation of skin-pass roll structures with significantly higher durability.

1. Introduction

1.1. Skin-pass rolling and micro lubrication mechanisms

Skin-pass rolling, also called temper rolling, is the final forming operation in the production line of sheet material for automotive applications. It is used to produce a defined surface condition, to calibrate the sheet thickness and to avoid a possible Lüders elongation by reducing the yield point phenomenon. The creation of a defined surface condition aims to improve the formability in subsequent deep drawing operations and to improve the paint adhesion without affecting negatively the optical appearance of the sheet in painted condition. Typically, a low degree of deformation ($\phi = 0.5–2\%$) is used to emboss the roll structure into the sheet surface. Textured rolls are commonly also used in the last stand of the tandem mill. This pre-texturing is often necessary to reach a demanded final sheet roughness and to avoid sticking of the coiled material during annealing (Simão et al., 1994).

The effect of an improved formability in deep drawing operations of textured sheets originates from beneficial lubrications effects which can occur on surfaces under plastic deformation. During a sheet metal forming process, the surface roughness is continuously flattened and the free volume for lubricants decreases. As a consequence, the lubricant can either escape the area of highest contact pressure or is entrapped in closed surface structure elements. In the latter case, a pressure build up can occur which carries a share of the overall contact pressure and presses the lubricant in surrounding areas of direct metal contact, thereby reducing friction and enlarging the formability of the sheet.

The basic knowledge about these mechanisms still bases on the experiments of Azushima and Kudo (1995) and Bech et al. (1998), who used a transparent die to make the lubricant behaviour accessible to direct visual observation. They distinguished two different pressure build up mechanisms, see Fig. 1.

The microplasto-hydrostatic-lubrication (MPHSL) is said to occur in closed surface voids under plastic deformation when the pressure of the lubricant q_0 exceeds the surrounding contact pressure p_c. Then, the lubricant escapes in the direction of lowest contact pressure. In contrast to this, the microplasto-hydrodynamic-lubrication (MPHSL) occurs under higher relative velocities and higher viscosities of the lubricant due to a viscosity-

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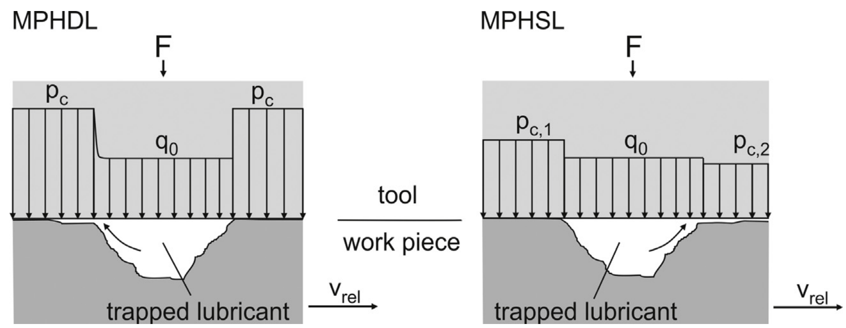

Fig. 1. Pressure distribution during microplasto-hydrodynamic and microplasto-hydrostatic lubrication.

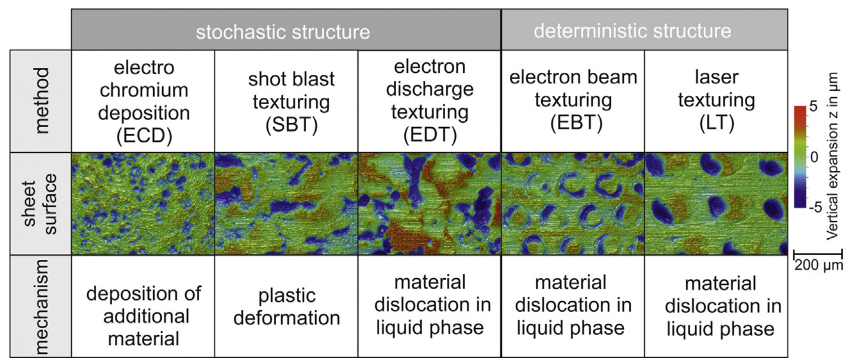

Fig. 2. State-of-the-art techniques for texturing of skin-pass roll.

induced pressure build up in the lubricant, which presses the lubricant in direction of the movement out of the void.

Considering the surface geometry, it can be assumed that some prerequisites are needed to enable these lubrication mechanism: the surface must exhibit separated, closed void volumes, so called lubrication pockets, which enable an encircling form closure to the die in the forming process. If there is no such contact, the lubricant will prematurely escape the pocket without pressure build-up. For this reason, the closed void volumes should be arranged as high as possible in the roughness distribution of the surface to allow a swift hydrostatic pressure build-up, which also supports the hydrodynamic effect. Therefore, elevated surface elements on the sheets beside the pockets must be avoided. Furthermore, the pockets must be of smaller size than the overall contact area.

1.2. Texturing techniques for skin-pass rolls

The necessary texture on skin-pass rolls for embossing these closed void volumes can be obtained by different texturing techniques. Fig. 2 shows an overview over the most common techniques as well as the resulting sheet surface measured by white-light-interferometry.

Principally, three different mechanisms are utilised for this texturing: the deposition of additional material, plastic deformations in the solid state, or a dislocation of material in the molten state. The listed techniques can be distinguished concerning the resulting structure in stochastically or deterministically working treatments. Although the question of how an ideal sheet structure looks like is still not convincingly answered, there are substantial indications that especially deterministic structures are capable to enhance the

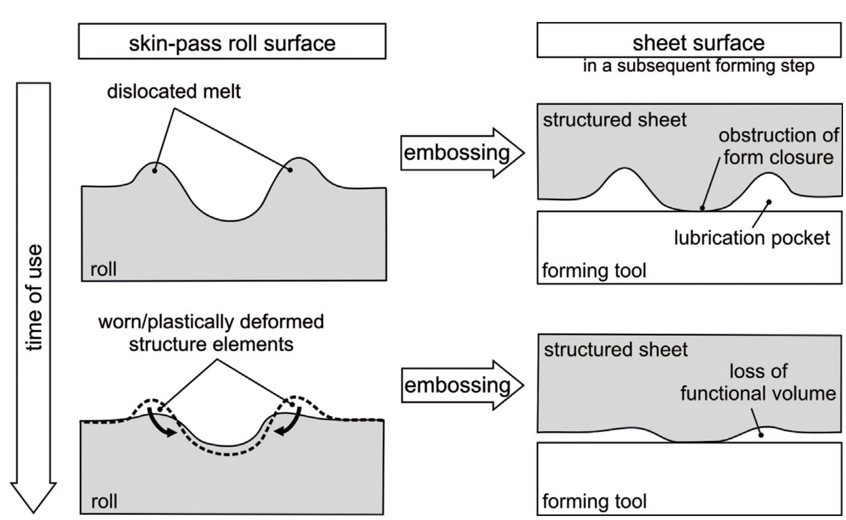

Fig. 3. Embossing results of a textured roll affected by wear.